Historic, archived document

Do not assume content reflects current
scientific knowledge, policies, or practices.

A381
R31Ab
Cop. 2

ARS-74-20
MAY 1960

LIBRARY
CURRENT SERIAL RECORDS
SEP 9 - 1960
U. S. DEPARTMENT OF AGRICULTURE

RESEARCH

on utilization of

SUGAR BEETS

a summary of progress

1949 / 1960

AGRICULTURAL RESEARCH SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

THIS REPORT summarizes research on utilization of sugar beets during 1949-1960 in the Western Utilization Research and Development Division of the Agricultural Research Service, U.S. Department of Agriculture, Albany 10, Calif. Within this Division, studies on composition of sugar beets, sugar, and processing juices are conducted in the Field Crops Laboratory and processing studies in the Engineering and Development Laboratory.

Supervisory staff members for the sugar beet utilization research program are M. J. Copley, Director of the Western Utilization Research and Development Division; G. O. Kohler, Chief, Field Crops Laboratory; W. D. Ramage, Chief, Engineering and Development Laboratory; R. M. McCready, In Charge, Sugar Beet Investigations.

This information was prepared in the Western Utilization Research and Development Division by R. M. McCready.

Contents

	page
Sugar beet processing laboratory	3
Processing studies	4
Post-harvest sucrose losses	5
Fundamental composition studies	7
Sugar crystallization	9
Improvement in sugar quality	10
Pulp polysaccharides	10
Dried sugar beets as carbohydrate in broiler diets	11
Utilization of sugar beet tops	11
Sugar as a chemical raw material	11
Literature cited	13

RESEARCH ON UTILIZATION OF SUGAR BEETS - 1949-1960

Research on sugar beets in the Western Utilization Research and Development Division was begun in July, 1948. The studies were stimulated by processors' needs for fundamental information on which to base development of new and improved processing methods, needs for methods to predict processing characteristics of various types of beets, and their desire to increase efficiency and lower the costs of beet sugar manufacture. This type of information still is urgently needed for the improvement of a manufacturing operation that has undergone few basic changes during the past 50 years (27).

Early researches, published in 1953 and 1954, demonstrated that the presence of lactic acid in diffusion juices was due to bacterial fermentation of sugar occurring mainly in the diffusion batteries (41, 42). This finding focused attention on the need for critical investigation of all the operating variables in each unit process. The sugar beet industry was favorably impressed with the results of this type of work and in 1954, under the terms of a Cooperative Agreement, the Beet Sugar Development Foundation made available $45,000 for use in equipping a sugar beet processing laboratory located in the Western Utilization Research and Development Division.

Sugar Beet Processing Laboratory

Prior to installation of the beet sugar processing laboratory, about a year and a half was spent on engineering studies. It was necessary to design the pieces of processing equipment and in most cases to have them custom built (19).

The continuous steps (diffusion, carbonation, and evaporation) were matched for size and integrated so that retention times were suitable at the chosen processing rate. The remaining steps (washing, slicing, mixing, filtration, second carbonation, and crystallization) were designed for batch operation.

The sugar beet processing laboratory is now equipped to the point where all operations from the cutting of beets to crystallization of sugar from thick juice can be performed (~~Fig. 1~~). The equipment includes a cosette cutter, a sample mixer, Roberts diffusion battery, a Bruniche-Olsen continuous counter-current diffuser, a continuous liming and carbonation unit for diffusion juice purification patterned after one designed

by R. A. McGinnis, a vacuum evaporator, and instrumentation required for control and analysis of factory operation. Besides these basic units there is auxiliary equipment such as an ion exchange water conditioner, heat exchangers, continuous feeder for the diffuser, juice cooling unit, steam-jacketed kettles for second carbonation, and filtration equipment.

Processing Studies

Research under a Research and Marketing Act contract, conducted by Utah State University and Agricultural Experiment Station, sought information on the number and size of beet samples required for experiments dealing with processing. Concentrations of constituents of sugar beets vary with genetic makeup, soil, climate, and other influences. The manner and spread of expected variation in commonly used commercial varieties were not previously known. Before adequate sampling procedures could be devised for processing, beet storage, and other researches, the amount and nature of this variability had to be established.

Two important commercial varieties--Stewart's variety 53104-0 and U.S. 22 Improved--grown under high and low levels of nitrogen fertilization in four different geographic locations constituted the material analyzed. Fifty beets were analyzed in duplicate for 12 characters which included weight, girth, total nitrogen, amino nitrogen, total glutamate, total anionic constituents (total acid), oxalic acid, malic acid, marc, galactinol, raffinose, and sucrose. The data were analyzed for variance, variance components, coefficients of variation, and simple correlations between constituents (17).

A chart was prepared which serves as a guide to the number of beets required for a chosen level of precision in analyses for chemical constituents of the presently used commercial varieties that were studied (Fig. 2). The proper number of beets can be read directly from the chart. To obtain a coefficient of variation of 1 percent in analysis for sucrose, about 50 beets are required, while sampling for gultamate with the same accuracy requires about 6,000 beets.

Staff chemists have determined the distribution of sugar throughout sugar beet roots, methods of obtaining reliable samples for sugar analyses, and other sampling procedures for use in the processing laboratory (47). It was found that beets sliced into cossettes and then mixed thoroughly provided adequate samples for sugar analyses. Both preheating of cossettes to inactivate enzymes prior to extraction (22) and neutralization of battery supply water (35) were promising improvements in beet processing technology.

In conjunction with processing studies, two contracts were negotiated with the University of Michigan. One contract involved the use of steam to disrupt the cells of beet tissue, but the process presents some inherent difficulties, such as sugar removal from the disintegrated tissue, that may preclude commercial use (3-7). A second contract involved the construction and testing of a laboratory-scale continuous countercurrent diffuser for studying the variables of extracting sugar from beet tissue. The findings of these researches were of sufficient merit to justify further studies.

Studies of the amount of lime, carbonation temperature, retention time in the carbonator, and alkalinity of the first carbonation juice revealed that alkalinity is the most important variable in first carbonation. Effects of changing retention time and temperature of the juice in these experiments were not significant (20).

Processing experiments on sugar beets infected with virus yellows and those without the disease showed that the filtration and sedimentation rates of infected beets were poorer, and that the disease tends to produce changes, all toward lower quality juices (10).

Soil nitrogen fertilization increases the concentration of sugar beet nitrogen. The effects of sugar beet nitrogen on processing were studied with samples of beets from widely spaced sugar-to-total-nitrogen ratios. The high-nitrogen beets produced juice of lower color, increased lime salts, increased glutamate content, and increased soluble nitrogen levels. All of these criteria except color are considered deleterious to processing. Except for the value of glutamate as a byproduct, these soluble impurities would carry more sugar into molasses than is usually the case (9, 21).

Post-Harvest Sucrose Losses

A problem closely related to, and essentially a part of, processing is post-harvest losses of sugar from beets. In many areas of the United States an accepted and necessary practice is to harvest the beets an appreciable time prior to processing. The beets are then stored in large piles at the factory or at countryside, centralized dumps. Beets may remain in the piles for as long as three months.

Sugar is lost during any storage period. Losses are due to metabolic processes in the beet tissues and through the action of invasive microorganisms. Unavoidable sugar losses are due to respiration of harvested

sugar beets wherein sucrose is utilized to provide the energy for their living functions. Under ideal conditions less than 0.1 pound and under unfavorable conditions more than 1.0 pound of sucrose is lost per ton of beets per day. If unobjectionable chemicals could be used to slow down one or more of these reactions without harming the beets, it would be possible to save a large part of the sugar presently lost in beet storage piles.

In order to devise means of decreasing sugar losses due to respiration of beets in storage piles, it is first necessary to understand the enzymatic mechanisms and pathways whereby sucrose is synthesized and metabolized. Studies have been initiated whereby such information will be obtained.

Micro amounts of sucrose and sucrose-phosphate have now successfully been synthesized by means of sugar beet enzyme preparations. These synthetic processes were found to be similar to those in wheat germ and peas and probably other higher plants. Both sucrose and sucrose-phosphate are synthesized by use of the sugar beet enzymes through a nucleotide sugar complex called uridine diphosphoglucose (31).

A contract for investigating the pathways of sucrose metabolism in stored beet roots was negotiated with Oregon State College. In this work radioactive tracer techniques were used as a research tool and time-course experiments were conducted to follow the fate of individual carbon atoms or radioactive compounds as they are metabolized by the roots.

It was shown that the pathways of respiration in sugar beet roots (75 percent by the Embden-Meyerhof and 25 percent by the direct oxidative scheme) are similar to those in tomatoes and other plants previously studied. Sugar beets are therefore not unique in their carbohydrate metabolism, and findings from researches on most higher plants can be confidently applied to sugar beets.

Carbon atoms of radioactive sucrose injected into roots are incorporated into various soluble and insoluble constituents. Similar results were found with injected radioactive carbon dioxide and radioactive glucose. These findings point to possible measures for controlling or retarding natural beet root respiration and thus to saving substantial amounts of sucrose.

By use of a combination of low temperature and a fungicide, it was possible to keep beets for long periods without spoilage. Thus it appears that sugar losses in stored beets can now be evaluated separately in regard to microbial spoilage, natural respiration, and other compositional changes

deleterious to processing.

The fungicide was used in these experiments under controlled laboratory conditions in an effort to differentiate between microbiological sugar losses and losses of sugar due to respiration. Commercial application of fungicides to control sugar losses was not considered.

Beet quality was determined by use of a standard extraction procedure at selected time intervals and the results were expressed as the ratio of sucrose to total soluble solids, usually referred to as purity. There was a progressive decrease in purity of stored beets at 55° F. The purity drop followed an increase in invert sugar, which is deleterious to processing. Beets stored at 55° F. for 90 days were comparable in quality to those stored at 34° F. for 180 days. No progressive changes in beet constituents such as total acids or nitrogen compounds were apparent. However, 60 days' storage of beets at 34° F. led to a fourfold increase in raffinose, while no accumulation of raffinose occurred in beets stored at ambient temperature of about 65° F. Raffinose appears to be formed at the expense of sucrose and is responsible for a marked decrease in rate of sucrose crystallization.

The above-mentioned researches were initiated to determine how the sugar losses occur and to provide information basic to control of these losses.

Fundamental Composition Studies

Following considerable effort in adapting existing analytical procedures for critical use and development of new ones for special requirements (2, 8, 13, 14, 16, 24, 28, 30, 32, 38, 44, 51, 52), a broad survey was undertaken and is continuing on the chemical composition of sugar beets and sugar beet processing liquors (25, 26, 29, 33, 34, 37, 39, 40, 43, 45, 51, 54).

From this series of studies it was shown that healthy sugar beet tissue contained only traces of lactic acid, whereas commercial diffusion juices contained from 0.06 to 0.4 percent (41). If only 0.1 percent of sucrose is converted to lactic acid in the factory, the dollar loss to the industry amounts to $200,000 to $400,000 per year. Both the grower and processor share this loss.

Mathematical calculations on the distribution of a chemical additive such as bactericide in a continuous sugar beet diffuser were made. Several interesting facts were revealed. For example, provided certain assumptions are true, the amount of additive in a cell may be many

times greater or only a small portion of the amount added after each transfer, depending on the partition coefficient and the position of the add cell (46). The results of these mathematical calculations explained the phenomenon that lactic acid produced in diffusion batteries at the expense of sucrose often was found in highest concentration in the middle of the battery.

The chemical components which make up the great bulk of sugar beets and sugar beet processing liquors have been pretty well elucidated. However, there are some constituents which are present in only small amounts, but which appear to have important bearings on various processing operations. As an example, there are materials in sugar beet molasses which interfere with the crystallization of sugar. A study was made of the composition of molasses obtained from 13 beet sugar factories representing the major beet sugar producing areas of the country (33, 36). About 60 percent of the materials in molasses other than sugar are nitrogenous compounds, 14 to 20 percent are potassium compounds, and 8 to 10 percent are acids other than pyrrolidone carboxylic acid (produced from glutamine as a result of processing sugar juice). This last compound makes up a large portion of the nitrogenous materials. Other nitrogen compounds in the molasses are betaine, amino acids, and complex types of compounds known as purines and pyrimidines. These last two groups of compounds have not yet been broken down into all their constituent fractions and study of them is continuing.

The nitrogenous compounds are of special concern to the sugar beet processor because of the belief that their presence adds to the difficulty of crystallizing sugar from the final purified juices. The amount of sugar lost in the molasses appears to be increasing from year to year and this loss is thought to be related to the increased use of nitrogenous fertilizers in the beet fields. There is little actual knowledge, however, as to the true role played by the various nitrogen compounds.

Quantitative studies of other constituents of molasses have been conducted and are continuing (34, 43, 45, 53, 54).

Acids, excluding amino acids, found in beet molasses include phosphoric, sulfuric, hydrochloric, lactic, glycollic, citric, malic, acetic, and formic acids (13, 24, 37, 38, 39). Some that are believed to be present but have not been determined quantitatively include glyceric, fumaric, succinic, nitric, and others.

As many as 18 amino acids have been quantitatively determined by means of paper chromatography in a number of beet juices and molasses samples (14).

These fundamental composition studies are continuing with the objective of completing the inventory of molasses constituents and correlating the composition with processing characteristics. About 25 percent of the nitrogen and 20 percent of nonsugar solids of molasses consist of unidentified chemical compounds. These must be identified before effective means can be devised for their removal (36) and thus increase processing efficiency.

Sugar Crystallization

Studies of the effect of various melassigenic compounds on sugar crystallization are now under way. The dilatometer, an apparatus modified for studies of crystallization of sucrose, measures the shrinkage in total volume of the mother liquor and sucrose as the sucrose crystallizes from solution. The chief advantage of the dilatometric method is that it provides an opportunity to obtain a large number of continuous time-concentration observations that might be used to calculate a rate constant for velocity of crystallization.

Surface and supersaturation appear to be the rate-controlling factors for pure sucrose crystallization at 30° C. No mathematical expression which adequately describes the concentration changes with time has been developed. Typical results obtained by this technique on pure sucrose-water systems cannot be expressed in a simple kinetic equation over the entire time range but only over a portion of the reaction time(55). These studies are continuing and may eventually provide a means for quantitative measurement of the effect of an impurity on the rate of sucrose crystallization.

Studies on the crystallization of sucrose with sonic waves were conducted at the College of the Holy Cross, Worcester, Mass. under contract. The treatment of supersaturated sucrose solutions with sound waves had no special effect on the rate of growth of single crystals but there was a slight increase of overall crystallization due to enhanced nucleation and false grain formation. The effects of sonic nucleation occurred with a minimum power level of 2 sonic watts per square centimeter and optimum frequency of 10 kc. It appears unlikely that sonic graining offers advantages over current practices (50).

Improvement in Sugar Quality

Some lots of beet sugar have been considered undesirable for use in bottlers' sirups because they seem to be the source of an unsightly flocculent material which gives a cloudy appearance to the bottled soft drinks. Since bottlers are among the largest users of sugar, the economic importance of the problem is apparent. Work on this problem has revealed that two saponin compounds are sometimes found in beet sugar (54). These saponins combine with other equally nonharmful contaminants in the purified sugar (such as slight traces of materials used to break the foam in the diffusion batteries) and, in the combined form, give rise to the floc. Methods of analysis for these saponins were developed and sent to sugar beet processors (51). Some processors using these analytical procedures for control purposes have developed operational methods for partial removal of saponins from beet sugar. Consequently, their floc problem has been partially alleviated.

Pulp Polysaccharides

The water-insoluble portion of sugar beets (marc or pulp) has also been under investigation (26). It consists principally of cellulose, pectin, hemicelluloses, araban, and protein. There are also complex carbohydrates containing the sugars xylose, galactose, and rhamnose in beet pulp (18), but their mode of occurrence has not been elucidated. Some of the marc constituents occur as colloidal compounds or become colloidal under certain processing conditions. The presence of colloidal impurities in diffusion juice interferes with subsequent processing operations, and removal of the colloids from the marc changes its physical characteristics. These findings have opened up an interesting new field.

In the beet sugar manufacturing process, wet exhausted pulp from the diffusers usually is passed through a screw press to reduce the water content to about 80 percent. Wet-pressed pulp is either sold to the farmer for feed, made into silage, or dried in rotary kilns.

Less than 390,000 tons of dried pulp is produced in the United States, but there is a potential of 650,000 tons. Since it contains approximately 25 percent pectin, 20 percent araban, and 6 percent galactan, the potential of polysaccharide byproducts is very encouraging (15, 18).

Araban has been extracted in high yields from beet pulp by a new procedure with hot lime water as the extractant (11, 12, 23). Comparative studies of the physical and chemical properties of some purified sugar beet arabans revealed that their molecular weight averages were

up to 37,000 (49). Araban was found to be unique among polysaccharides in its tendency to aggregate in water, fluoresce, and show anamolous behavior in the presence of dimethylformamide.

Continuing studies of araban may furnish information bearing on floc and turbidity problems and on the behavior of certain high polymers in solution.

Dried Sugar Beets as Carbohydrate in Broiler Diets

Experiments were conducted on the use of dried ground sugar-beet slices in broiler feed (48). In some feeding experiments with chicks, when 40 percent of the weight of their diet was dried beets, growth retardation was observed. At 20 percent no significant reduction occurred as compared with the control. Some lots of commercially dried beets could be fed in quantities up to 36 percent of the total diet of chicks, with their rate of growth equivalent to that obtained with corn. Commercially dried beets appeared to be better for chick feeding than those processed in the laboratory.

Utilization of Sugar Beet Tops

The first research contract on sugar beets was negotiated with the Colorado State University and Agricultural Experiment Station for a study of the dehydration of sugar beet tops as an economic means for preserving their nutrient values (1). Four ways of handling the tops were investigated: (1) reduction of moisture by pressing prior to dehydration, (2) reduction of moisture by ensiling prior to dehydration, (3) dehydration of a mixture of chopped leaves and pressed pulp, and (4) direct dehydration in a commercial drier. The last procedure appeared to be the most promising. The economics were reported to be favorable, and feeding tests showed the dehydrated tops had excellent nutritive value, but at present farmers have not adopted dehydration of tops.

Sugar as a Chemical Raw Material

Refined sucrose from cane and beets is a very pure chemical compound, 99.9 percent pure, available in quantity at low cost. It is one of the "big three" carbohydrates that are renewable sources of chemicals, as compared with the supplies of petroleum and coal. Because of its purity, availability, stability, and reactivity, sucrose offers an attractive material for industrial chemical utilization.

Preliminary experiments conducted in the field of "sucrochemistry" have revealed that methods for determining the reactivities of the various hydroxyl groups and for separating reaction products from complex mixtures are needed. Studies in progress are concerned with the formation of products wherein sucrose retains its molecular structure, with separation of the products, and with correlation of the results with available knowledge of the reactivity of primary and secondary hydroxyl groups of the sucrose molecule.

Literature Cited

1. Barmington, R. D., Davis, P. N., and Wilgus, H. S.
   1952. Conservation of Sugar Beet Tops by Dehydration. Colorado Agr. Expt. Sta. Tech. Bull. 47:1-88.
2. Bevenue, A., and Williams, K. T.
   1958. Quantitative Determination of Raffinose or Melibiose by Paper Chromatography. Arch. Biochem. & Biophys. 73: 291-295.
3. Brownell, L. E. and Zieminski, S. A.
   1957. Processing of Sugar Beets. U.S. Patent No. 2, 807, 560.
4. _____and Zieminski, S. A.
   1957. Treatment of Sugar Beets to Release Juice. U.S. Patent No. 2, 818, 358.
5. _____and Zieminski, S.A.
   1958. Machine for Pulping Sugar Beets. U.S. Patent No. 2, 858, 079.
6. _____and Zieminski, S. A.
   1959. Processing of Sugar Beets. U.S. Patent No. 2, 873, 220.
7. _____Zieminski, S. A., and Lee, T. H.
   1956. Recovery of Juice from Sugar Beets by Rupture of the Beet Cells. Chem. Engin. Prog. 52:314-318.
8. Goodban, A. E., Jaouni, T., and McCready, R. M.
   1959. Determination of Pulp Moisture. Submitted to Jour. Amer. Soc. Sugar Beet Technol.
9. _____Knowles, R. E., McCready, R.M., Morgan, A.I.
   Walker, H.G., Jr., Teranishi, R., Hac, Lucile R., and Walker, A.C.
   1959. Effects of Nitrogen Fertilization on the Behavior of Commercial and High Glutamate Sugar Beet Varieties. Submitted to Jour. Amer. Soc. Sugar Beet Technol.
10. _____Morgan, A.I., Teranishi, R., Walker, H.G. Jr., and McCready, R.M.
   1959. Some Effects of Virus Yellows on Sugar Beet Processing Quality. Submitted to Jour. Amer. Soc. Sugar Beet Technol.
11. _____and Owens, H.S.
   1956. Isolation and Properties of Sugar Beet Araban. Jour. Amer. Soc. Sugar Beet Technol. 9(2):129-132.
12. _____and Owens, H.S.
   1957. Chromatographic Fractionation of Sugar Beet Araban. Jour. Polymer Sci. 23: 825-829.
13. _____and Stark, J.B.
   1957. Rapid Method for Determination of Malic Acid. Anal. Chem. 29: 283-287.
14. _____Stark, J.B., and Owens, H.S.
   1953. Amino Acids Content of Sugar Beet Processing Juices. Jour. Agr. and Food Chem. 1: 261-264.
15. Kohler, G.O.
   1959. Symposium on Current Developments on Beet Byproducts. Submitted to Jour. Amer. Soc. Sugar Beet Technol.
16. Maclay, W.D., Potter, E.F., Erlandsen, R.F., and Owens, H.S.
   1954. Investigation of Factors Influencing the Sachs-Le Docte Method. Amer. Soc. Sugar Beet Technol. Proc. 8, Part 2: 298-302.
17. McAllister, D.R., Hurst, R.L., and Bennett, W.H.
   1959. The Variability of Sugar Beet Constituents as Influenced by Soil, Fertilization, Climate, and Variety. Submitted to Jour. Amer. Soc. Sugar Beet Technol.
18. McCready, R.M.
   1959. Polysaccharides of Sugar Beet Pulp. Submitted to Jour. Amer. Soc. Sugar Beet Technol.
19. Morgan, A.I., Barta, E.J., and Kohler, G.O.
   1959. Development of a Sugar Beet Processing Laboratory. Submitted to Jour. Amer. Soc. Sugar Beet Technol.
20. _____Goodban, A.E., Teranishi, R., Knowles, R.E., and McCready, R.M.
   1958. Effects of Some Variables on First Carbonation. Jour. Amer. Soc. Sugar Beet Technol. 10:396-402.
21. _____Teranishi, R., Goodban, A.E., Walker, H.G. Jr., Knowles, R.E., and McCready, R.M.
   1959. Effects of Sugar Beet Nitrogen on Diffusion and Carbonation. Submitted to Jour. Amer. Soc. Sugar Beet Technol.
22. Owens, H.S.
   1956. Inactivation of Enzymes in Beet Cossettes Prior to Diffusion. U.S. Patent No. 2, 754, 233.
23. _____and Goodban, A.E.
   1957. Isolation of Araban from Sugar Beet Pulp. U.S. Patent No. 2, 803, 567.
24. _____Goodban, A.E., and Stark, J.B.
   1953. Fractionation of Organic Acids in Sugar Beets by Ion Exchange Resins. Anal. Chem. 25:1507-1511.

25. Owens, H.S., Goodban, A.E., Stark, J.B., and Walker, H.G. Jr.
1951. Composition of Sugar Beets. The Sugar Jour. 14(2): 12-14.
26. _____McComb, Elizabeth A., and Deming, George W.
1954. Composition and Percentage of Marc in Some Varieties of Inbred Sugar Beets. Amer. Soc. Sugar Beet Technol. Proc. 8, Part 2: 267-271.
27. _____Rasmussen, C.L., and Maclay, W.D.
1951. Production and Utilization of Sugar Beets. Econ. Botany 5(4): 348-366.
28. _____Stark, J.B., and Goodban, A.E.
1953. Separation of Organic Acids. U.S. Patent No. 2,664, 41.
29. _____Stark, J.B., Goodban, A.E., and Walker, H.G. Jr.
1955. Beet Sugar Technology. Application of Compositional Knowledge to Beet Sugar Technology. Jour. Agr. and Food Chem. 3: 350-353.
30. Rorem, E.S.
1959. Ultraviolet Fluorescence of Quinine Sulfate for Detection of Phosphate Ester Spots on Paper. Nature 183: 1739-1740.
31. _____Walker, H.G. Jr., and McCready, R.M.
1959. Biosynthesis of Sucrose and Sucrose-Phosphate by Sugar Beet Leaf Extracts. Plant Physiol. 35(2): 269-272.
32. Stark, J.B.
1959. Multiple Sample, Continuous Dialyzer. Chemist Analyst 48(1): 17.
33. _____
1959. The Composition of Beet Molasses with Particular Reference to Nitrogenous Compounds. Submitted to Jour. Amer. Soc. Sugar Beet Technol.
34. _____and Goodban, A.E.
1952. Condensation Product of Pyrrolidone Carboxylic Acid and Formaldehyde. Jour. Amer. Chem. Soc. 74: 4966-4967.
35. _____and Goodban, A.E.
1957. Recovery of Sugar from Sugar Beets. U.S. Patent No. 2,801,940.
36. _____Goodban, A.E., and McCready, R.M.
1959. The Fractionation of Nitrogen Compounds in Beet Molasses. Submitted to Jour. Amer. Soc. Sugar Beet Technol.
37. _____Goodban, A.E., and Owens, H.S.
1950. Organic Acids in Sugar Beet Diffusion Juices. Amer. Soc. Sugar Beet Technol. Proc. 6:578-583.
38. _____Goodban, A.E., and Owens, H.S.
1951. Paper Chromatography of Organic Acids. Anal. Chem. 23: 413-415.
39. _____Goodban, A.E., and Owens, H.S.
1951. Composition of Sugar Beet Liquors. Indus. Engin. Chem. 43: 603-605.
40. _____Goodban, A.E., and Owens, H.S.
1952. Composition of Certain Beet Diffusion Juices from the 1950 Campaign. Amer. Soc. Sugar Beet Technol. Proc. 7: 688-691.
41. _____Goodban, A.E., and Owens, H.S.
1953. Beet Sugar Liquor. Determination and Concentration of Lactic Acid in Processing Liquors. Jour. Agr. and Food Chem. 1: 564-566.
42. _____Goodban, A.E., and Owens, H.S.
1954. Lactic Acid Fermentation in Beet Processing Juices. Amer. Soc. Sugar Beet Technol. Proc. 8, Part 2: 227-231.
43. _____Jaouni, T., and Bailey, G.F.
1956. The Purines, Pyrimidines, and Nucleosides in Beet Diffusion Juice and Molasses. Jour. Amer. Soc. Sugar Beet Technol. 9(3): 201-206.
44. _____Teranishi, R., and Bailey, G.F.
1957. Device for Monitoring Absorbance of Column Eluates in a Spectrophotometer. Anal. Chem. 29: 861-862.
45. _____and Wright, H.M.
1957. The Absence of Carbonate in Beet Molasses. Jour. Amer. Soc. Sugar Beet Technol. 9(7):566-567.
46. Stitt, Fred
1957. Theoretical Steady State Distribution of an Additivein Sugar Beet Diffusers. Jour. Amer. Soc. Sugar Beet Technol. 9: 611-631.
47. Teranishi, R., Patterson, R.L., and Owens, H.S.
1956. Sampling of Sugar Beets for the Processing Laboratory. Jour. Amer. Soc. Sugar Beet Technol. 9(1): 74-77.

48. Thompson, C.R., and Kohler, G.O.
1959. Dried Sugar Beet Roots as a Source of Carbohydrate for Broiler Rations. Submitted to Poultry Sci.
49. Tomimatsu, Y., Palmer, K.J., Goodban, A.E., and Ward, W.H.
1959. Molecular Weights of Sugar Beet Araban Fractions. Jour. Polymer Sci. 36: 129-139.
50. Van Hook, Andrew, Radle, W.F., Bujake, J.E., and Casazza, J.J.
1957. Crystallization of Sucrose with Sonic Waves. Jour. Amer. Soc. Sugar Beet Technol. 9(7): 590-595
51. Walker, H.G. Jr.
1956. Determination of Saponins in Refined Beet Sugars. Jour. Amer. Soc. Sugar Beet Technol. 9(3); 233-237.
52. _____and Erlandsen, Roberta
1951. Rapid Method for Determination of Betaine. Anal. Chem. 23: 1309-1311.
53. _____and Owens, H.S.
1952. The Hydrolysis Rate of Betaine Amide and Ester Chlorides. Jour. Amer. Chem. Soc. 74: 2547-2549.
54. _____and Owens, H.S.
1953. Beet Sugars; Acid-Insoluble Constituents in Selected Samples. Jour. Agr. and Food Chem. 1: 450-453.
55. _____Teranishi, R., Knowles, R.E., Kohler, G.O., and McCready, R.M.
1959. A Study of Sucrose Crystallization by the Dilatometric Method. Submitted to Proc. 10th Cong. Internatl. Soc. Sugar Cane Technol.

GPO 980172